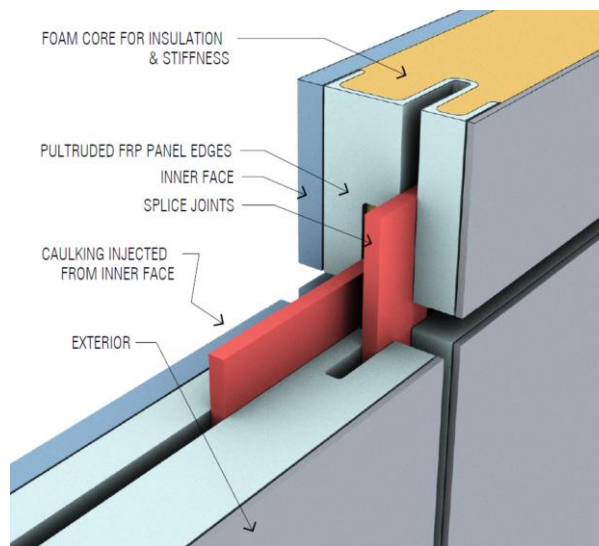


Multifunctional Composite Panels for Building Envelope Retrofits



Oak Ridge National Laboratory

Diana Hun, Subprogram Manager for Building Envelopes

865.574.5139

hunde@ornl.gov

Project Summary

Timeline:

Start date: 10/1/18

Planned end date: 9/30/20

Key Milestones

1. Joint designs for composite panels that are insulated with polyiso foam; 12/31/18
2. Air leakage rate of panel w/ proposed joint designs is $\leq 0.2 \text{ L/s}\cdot\text{m}^2$ at 75 Pa and have no water leaks when tested according to ASTM E283 and ASTM E2268, respectively; 9/30/19

Budget:

Total Project \$ to Date:

- DOE: \$337K
- Cost Share: ~\$2K

Total Project \$:

- DOE: \$337K
- Cost Share: ~\$10K

Key Partners:

K R E Y S L E R &
A S S O C I A T E S

Project Outcome:

Designs for fiber-reinforced polymer (FRP) composite panels that can be used to overclad existing buildings. The FRP panels will combine the cladding, and the heat, air and moisture barriers in a lightweight and thin profile. The designs will focus on integrating the insulation with FRP facers and maintaining continuity of the air and moisture barrier at the panel joints.

Team

K R E Y S L E R &
A S S O C I A T E S



Integration of insulation and
manufacturing of prototype panels

Panel and joint evaluation

Joint design



Bill Kreysler



Robert Shear



Joshua Zabel



Diana Hun, PhD



Jerald Atchley

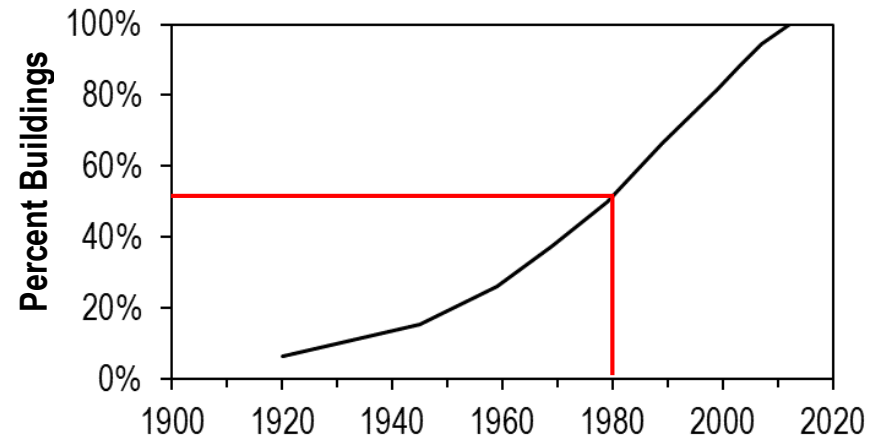
Team expertise

- Building envelopes
- Manufacturing of large-scale fiber-reinforced polymer panels
- Air- and water-resistive barriers
- Insulation materials
- Evaluations in large-scale chambers

Challenge

- About 50% of existing residential and commercial buildings lack or have minimal insulation as they were built before energy codes
- The technical potential from adding R12 to existing residential and commercial walls is ~0.6 quads of energy by 2030*
- DOE's Building Technologies Office is seeking for methods to retrofit building envelopes
 - Cost-effective
 - Easy and fast installation
 - Lightweight
 - Aesthetically pleasing
 - Thin profile
 - Minimally disrupt occupants → prefabrication

Year of Construction of Commercial Buildings**



*2014 DOE Windows and Building Envelope Roadmap

**2012 Commercial Buildings Energy Consumption Survey

Prefabricated Overclad Panels

- Prefabricated overclad panels
 - Installed over existing envelope
 - Include all the necessary envelope components
- RetrofitNY program
 - Targeting multifamily buildings
 - Initial findings suggest that overclad panels may be not cost-effective in the US
- Delivery and site installation account for ~20 to 40% of total cost



Means to decrease cost

Thinner panels

- More panels per truck → ↓ transportation cost
- Smaller connections → ↓ installation cost

Lighter panels

- May not need to reinforce existing structures
- Lower transportation cost
- Smaller/fewer connections → ↓ installation cost
- Smaller crane → ↓ installation cost

Common Overclad Panels for Multifamily w/ ≤ 4 Stories

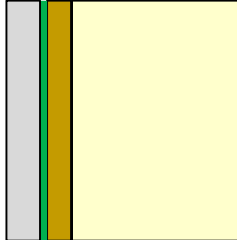
- Type V combustible assemblies
- Common panel assembly:

Wood Framing w/ Cavity Insulation

Weight $\cong 5$ psf

Thickness $\cong 4.5$ "

Effective R-value $\cong 12$



- Fiber cement board cladding
- Air- and water-resistive barrier
- $\sim 7/16$ " OSB
- 2x4 wood studs at 16" on center
- R13 fiberglass batts in wall cavities



Overclad Panels for Multifamily w/ > 4 Stories

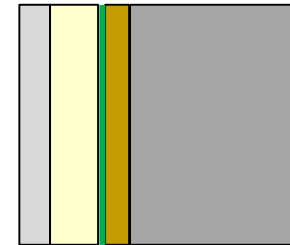
- Exterior continuous insulation needed to achieve effective R-value
- Assembly needs to comply with NFPA 285

Potential panel assembly: Steel Framing w/ Exterior Continuous Insulation

Weight \cong 6 to 8 psf

Thickness \cong 5.5"

Effective R-value \cong 12



- Fiber cement board cladding
- 1" polyiso insulation board
- Air- and water-resistive barrier
- 5/8" exterior fire-rated sheathing
- Steel studs at 16" on center
- R11 fiberglass batts in wall cavities

Lighter & Thinner: Fiber-Reinforced Polymer (FRP) Panels



Kreysler and Associates manufactured FRP panels as a rainscreen for the expansion of the San Francisco Museum of Modern Art

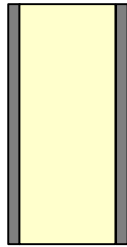
- Lightweight
- NFPA 285 compliant
- ~5 ft × ~30 ft panels (can be larger)



Insulated FRP Panels for Multifamily w/ ≤ 4 Stories

Insulated FRP Panel

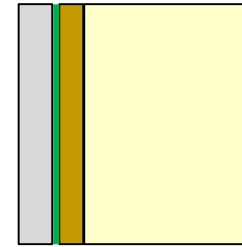
Weight $\cong 3$ psf
Thickness $\cong 2.25$ "
Effective R-value $\cong 12$



- $\sim 1/8$ " exterior FRP facer
- 2" polyiso insulation board
- $\sim 1/8$ " interior FRP facer

Wood Framing w/ Cavity Insulation

Weight $\cong 5$ psf
Thickness $\cong 4.5$ "
Effective R-value $\cong 12$



- Fiber cement board cladding
- Air- and water-resistive barrier
- $\sim 7/16$ " OSB
- 2x4 wood studs at 16" on center
- R13 fiberglass batts in wall cavities

Insulated FRP vs wood panels

- $\sim 40\%$ lighter
- $\sim 50\%$ thinner \rightarrow ship 2 \times more panels per truck load
- Fewer components could lead to better assembly and performance

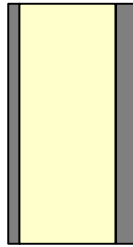
Insulated FRP Panels for Multifamily w/ > 4 Stories

Insulated FRP Panel

Weight \cong 4.5 psf

Thickness \cong 2.6"

Effective R-value \cong 12



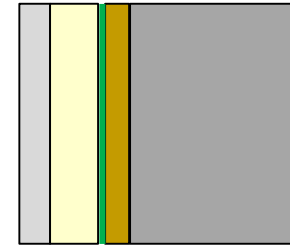
- ~ 1/4" exterior FRP facer
- 2" polyiso insulation board
- ~ 3/8" interior FRP facer

Steel Framing w/ Exterior Continuous Insulation

Weight \cong 6 to 8 psf

Thickness \cong 5.5"

Effective R-value \cong 12



- Fiber cement board cladding
- 1" polyiso insulation board
- Air- and water-resistive barrier
- 5/8" exterior fire-rated sheathing
- Steel studs at 16" on center
- R11 fiberglass batts in wall cavities

Insulated FRP vs steel panels

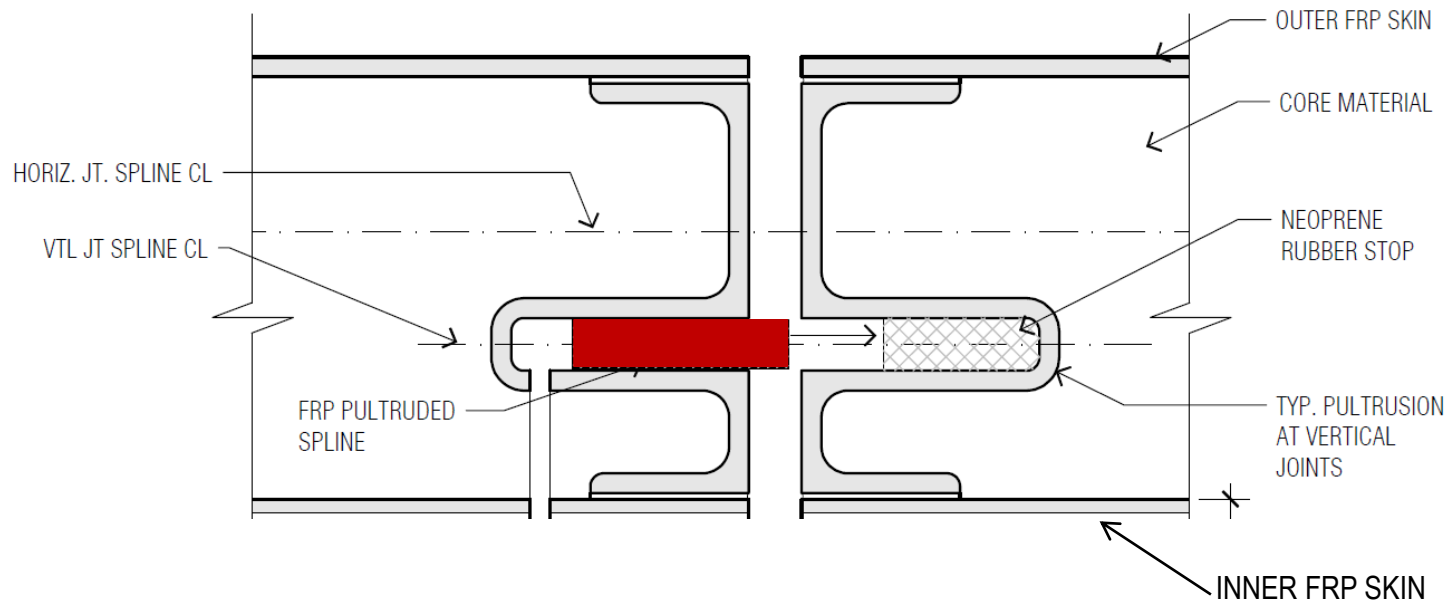
- ~25% lighter
- ~50% thinner → ship 2× more panels per truck load
- Fewer components could lead to better assembly and performance

Objectives

- Integrate insulation with FRP facers
- Design and evaluate performance of panel joints that maintain continuity of the air- and moisture-resistive barrier
 - Joints are among the weakest points in panelized construction

Cross-Section of Preliminary Joint Design

Spline Joint



How it works

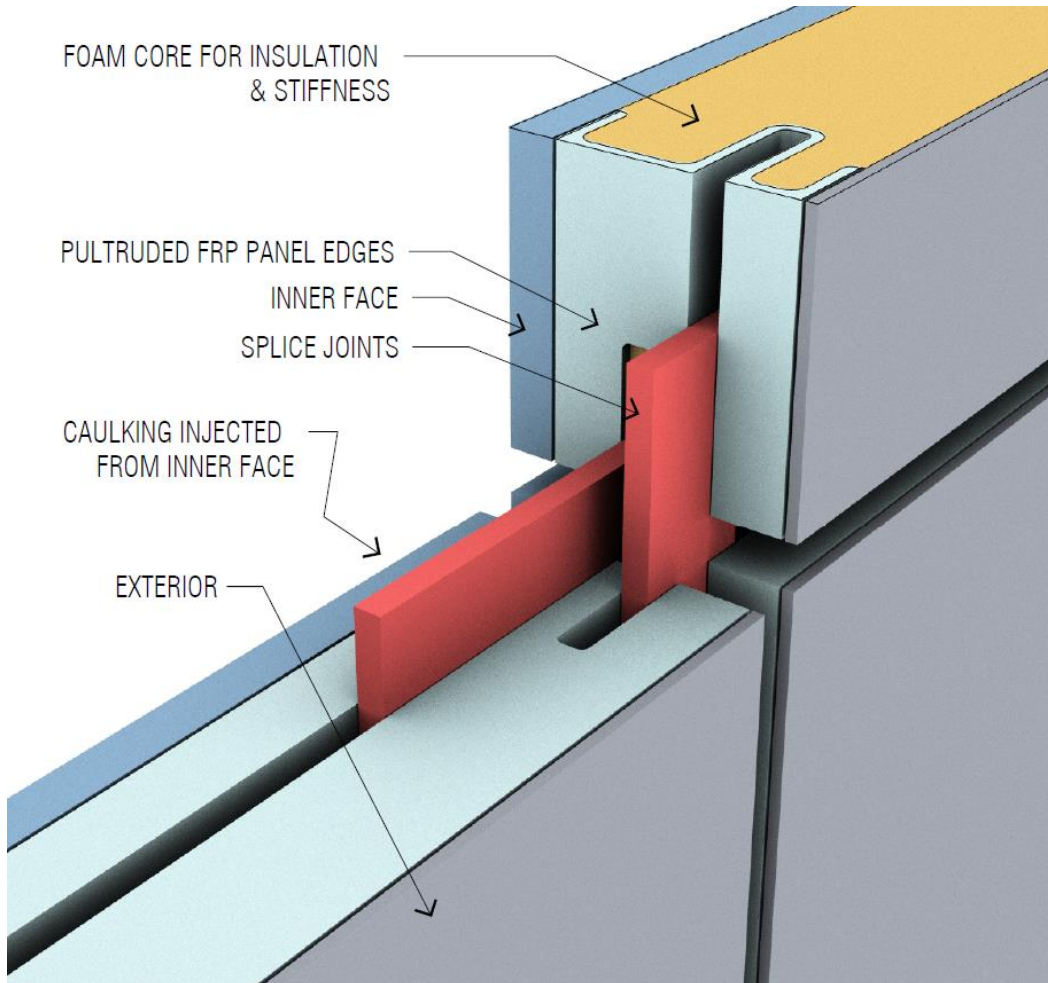
- Panel is installed while spline is flushed with the edge of the panel
- Spline is slid to close the joint gap after both panels are installed
- Joint ends can be caulked for aesthetics

Variables to be evaluated

- Thickness of inner and outer facers
- Methods to slide spline at construction site
- Ease of installation

Isometric View of Preliminary Joint Design

Spline Joint



- Advantages

- Less dependent on installer than joints sealed w/ caulk
- Staggered vertical and horizontal splines make joint design at corners more robust
- Damaged panels can be easily removed by cutting splines

- Design of interior facer

- Test 1 – Type V panels: thicker for multifamily buildings > 4 stories
- Test 2 – NFPA 285 panels: thinner for multifamily buildings \leq 4 stories

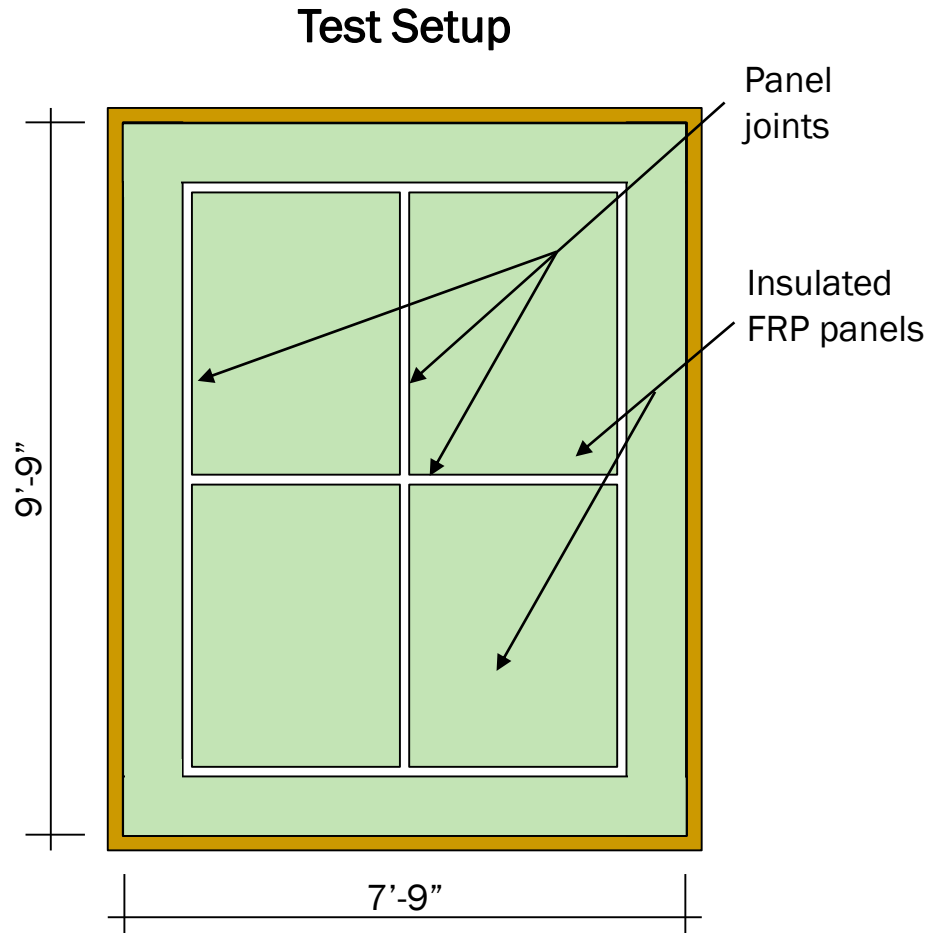
Heat, Air and Moisture Penetration Chamber



Capabilities

- Aging through temperature and pressure cycles
- Air leakage rates
- Water leakage at static and dynamic conditions

Large-Scale Chamber Evaluations



Evaluations

- Joint types
 - Vertical
 - Horizontal
 - Corner
 - Perimeter
- Ease of installation
 - Spline
 - Overclad
- Spline movement from simulated expansion and contraction

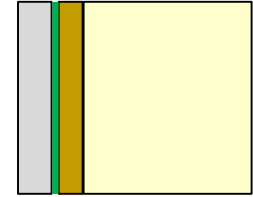
FY19 Remaining Work

- Manufacture small-scale mockups of spline design
 - Evaluate ease of assembly
- Manufacture NFPA 285 overclad panel
 - Thicker interior facer
 - Evaluate
 - Robustness after transportation, handling and installation
 - Ease of assembly
 - Installation over “existing” wall
 - Perform chamber tests and improve design
- Manufacture Type V overclad panel
 - Thinner interior facer
 - Integrate lessons from NFPA 285 overclad panel tests
 - Repeat evaluations made with NFPA 285 overclad panel
- Conduct preliminary cost estimates

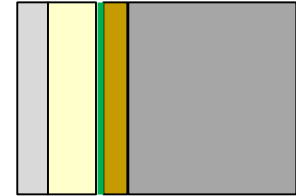
FY20 Remaining Work

- Replace polyiso board with vacuum insulated panel (VIP)
 - VIP R-value ~35/in
 - Reduce thickness of FRP panel
 - Ship 2.5× more panels than FRP w/ polyiso
 - Ship 4.5× more panels than steel-framed panels
 - Ship 5.5× more panels than steel-framed panels
- Design new panel joint
 - Spline joint likely not feasible with VIPs
- Repeat FY19 evaluation procedure

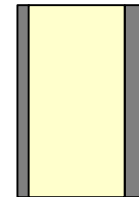
Wood-Framed Panels



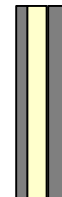
Steel-Framed Panels



FRP Panels w/ Polyiso Foam



FRP Panels w/ VIP



Stakeholder Engagement

- Mid-stage research
- Attended workshops on multi-family building retrofits
 - New York State Energy Research and Development Authority (NYSERDA)
 - California Energy Commission (CEC)
 - Insulated FRP panels could be a good fit for multifamily retrofit efforts
- Initiated discussions with the Institute for Advanced Composite Manufacturing Innovation (IACMI) and the University of Tennessee to explore mechanisms to reduce cost of FRP panels
 - Designs for faster window installation
 - Easy-to-install connections to existing building



Thank You

Oak Ridge National Laboratory

PI: Diana Hun, Subprogram Manager for Building Envelopes
hunde@ornl.gov

REFERENCE SLIDES

Project Budget

Project Budget: FY19: \$160K FY20: \$177K Total: \$337K

Variances: none

Cost to Date: \$20K

Additional Funding: none

Budget History			
FY 2019		FY 2020 (planned)	
DOE	Cost-share	DOE	Cost-share
\$160K	~\$5K	\$177K	~\$5K

Project Plan and Schedule

Deliverable/Milestone	FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Selected joint design for panels with polyiso boards.	Completed							
Designed the setup that will be used to install the test walls in the heat, air, and moisture chamber and that will allow the joint to expand and contract.		Completed						
Air leakage rate of NFPA 285 panel w/ proposed joint designs is ≤ 0.2 L/s·m ² at 75 Pa and have no water leaks when tested according to ASTM E283 and ASTM E2268, respectively.		Completed	Regular					
Air leakage rate of Type V panel w/ proposed joint designs is ≤ 0.2 L/s·m ² at 75 Pa and have no water leaks when tested according to ASTM E283 and ASTM E2268, respectively.			Regular	Go/No Go				
Optimization of Thermal Conductivity								
Selected joint design for panels with VIPs.					Regular			
Designed the setup that will be used to install the test walls in the heat, air, and moisture chamber and that will allow the joint to expand and contract.						Regular		
Air leakage rate of NFPA 285 panel w/ proposed joint designs is ≤ 0.2 L/s·m ² at 75 Pa and have no water leaks when tested according to ASTM E283 and ASTM E2268, respectively.						Regular	Regular	
Air leakage rate of Type V panel w/ proposed joint designs is ≤ 0.2 L/s·m ² at 75 Pa and have no water leaks when tested according to ASTM E283 and ASTM E2268, respectively.							Regular	Regular

■ Completed
 ■ Regular
 ■ Go/No Go